CLAIMS

1. Method for radiographic imaging, comprising a step (d) which consists in introducing, into calculation means (17), first digitized radiological data from signals delivered by means (6) of detection of X-rays and corresponding to pixels of a first image of an anatomical part comprising an osseous body and scanned, in a first incidence, with a beam of X-rays having an energy spectrum distributed about at least two energies, these first data comprising, for each pixel, coordinates of the pixel in the first image and absorptiometry values designed to calculate the bone mineral density of the osseous body, referred to a surface area unit, characterized in that it comprises a step (e) which consists in determining the value of a composite index using, on the one hand, first digitized radiological data, and, on the other hand, a three-dimensional generic model of said osseous body.

2. Method according to Claim 1, in which, prior to step (d) which consists in introducing the first radiological data into the calculation means (17), the following steps are implemented which consist in:
   (a) scanning at least one anatomical part comprising said osseous body, by irradiating it in at least the first incidence with at least one beam of X-rays having an energy spectrum distributed about at least two energies,
   (b) detecting, by virtue of detection means (6), the energy of the radiation corresponding to the X-rays scanning, in the first incidence, each anatomical part comprising said osseous body and transmitted by each of the scanned parts, and delivering, from the detection

means (6), signals corresponding to the radiation transmitted, and

(c) digitizing and recording these signals delivered by the detection means (6) and corresponding at least to the first incidence, in order to constitute the first radiological data.

3. Method according to one of the preceding claims, in which step (d) comprises the operation which consists in reconstructing at least a first two-dimensional image of the bone mineral density of each scanned part of said osseous body, using the first radiological data.

4. Method according to one of the preceding claims, also comprising a step (d') which consists in introducing, into the calculation means (17), second digitized radiological data from signals delivered by means (6) of detection of X-rays and corresponding to pixels of a second image of the anatomical part comprising said osseous body and scanned with a beam of X-rays in a second incidence not parallel to the first incidence, and in which the second radiological data are introduced in step (e), for determining the value of the composite index.

5. Method according to Claim 4, in which, prior to step (d') which consists in introducing the second radiological data into the calculation means (17), the following steps are implemented which consist in:

(a') scanning at least one anatomical part comprising said osseous body, by irradiating it in the second incidence with a beam of X-rays having an energy spectrum distributed about at least one energy;

(b') detecting, by virtue of the detection means (6), the energy of the radiation corresponding to the X-rays scanning, in the second incidence, each anatomical part comprising said osseous body and transmitted by each of the scanned parts, and delivering, from the detection means, signals corresponding to the radiation transmitted, and

(c') digitizing and recording the signals delivered by the detection means (6) and corresponding to the second incidence, in order to constitute the second radiological data.

6. Method according to Claim 5, in which the first and second radiological data are obtained respectively in the first incidence and second incidence, by two consecutive scans of said anatomical part.

7. Method according to Claim 5, in which the first and second radiological data are obtained by simultaneous scanning, in the first incidence and second incidence, of said anatomical part.

8. Method according to one of Claims 4 to 7, in which step (d) comprises the operation which consists in reconstructing a second two-dimensional image, chosen from between a standard radiographic image and an image of the bone mineral density, of each scanned part of the body containing said osseous body, using the second radiological data.

9. Method according to one of the preceding claims, in which step (e) comprises the following subsidiary steps consisting in:

(e_1) identifying, on at least the first image, predetermined markers corresponding to said osseous body,

(e_2) determining in the three-dimension reference system, and by virtue of first means of reconstruction, the geometric position of each marker identified in step (e_1), and

(e_3) determining, by virtue of second means of reconstruction, the three-dimensional shape of an actual model representing said osseous body, by deformation of a predetermined generic model while at the same time keeping markers of this generic model in coincidence, during deformation, with the markers reconstructed by the first means of reconstruction.

10. Method according to Claim 9, in which the generic model is deformed in such a way that the actual model follows a shape which is as close as possible to an isometry of the generic model.

11. Method according to Claim 9, comprising a step (g) which consists in determining, in a three-dimension reference system, and by virtue of third means of reconstruction, the geometric position of three-dimensional contours belonging to said osseous body, by bringing markers identified in step (e_1) into line with three-dimensional contours of the generic model which are projected onto at least the first image, and by performing a non-homogeneous geometric deformation of the generic model in order to improve the match between information originating from at least the first image and information representative of the actual model.

12. Method according to one of Claims 9 to 11, in which:

- during the step (e_1), some of the identified markers, called "non-stereo-corresponding control markers", are visible and identified only on a single image,
- and, during the step (e_2), the geometric position of each non-stereo-corresponding control marker (C7-C25) in the three-dimension reference system is estimated from the generic model, by displacing the non-stereo-corresponding control markers of the generic model, each on a straight line joining:
  . on the one hand, the X-ray source (5, 11) to the origin of the image in which a projection of this non-stereo-corresponding control marker is visible and identifiable,
  . and, on the other hand, the projection of this marker onto this image,

  the non-stereo-corresponding control markers (C7-C25) thus being displaced to respective positions which minimize the global deformation of the generic model of the object to be observed.

13. Method according to Claim 12, in which, during the operation (e_3), the value of the quadratic sum is minimized:

$$S = \lambda.\sum_{i=1}^{m} k_i.(x_i - x_{i0})^2,$$

where λ is a constant coefficient, *m* is a whole number of imaginary springs joining each marker (C1-C25) of the generic model to other markers of this model, k_i is a predetermined value of stiffness of the imaginary spring of index *i*, x_{i0} is the length of the imaginary spring of index *i* in the initial generic model, and x_i is the length of imaginary spring of index *i* in the generic model during deformation.

14. Method according to one of Claims 9 to 11, in which:
    - during the step (e_1), at least some of the markers are stereo-corresponding control markers (C1-C6) visible and identified on the first image and another image,
    - and, during the step (e_3), the geometric position of the stereo-corresponding control markers (C1-C6) is directly calculated from measurements of position of the projections of these markers onto the first image and the other image.

15. Method according to one of the preceding claims, comprising a step (h) which consists in performing a radiographic calibration of the three-dimensional environment of said osseous body by defining the three-dimensional reference system in which are expressed the coordinates of each X-ray source (5) and of the detection means (6) for each incidence.

16. Method according to one of the preceding claims, in which, during the operation (e), contour lines corresponding to limits of said osseous body and/or to lines of greater grey level density inside these limits are plotted on each image.

17. Method according to one of the preceding claims, in which the composite index is a parameter chosen from among
    . a specific parameter of the bone geometry, chosen from among the angle, length, surface and volume of an osseous part,
    . a physical parameter chosen from the bone mineral density and the mass of an osseous part,

. a mechanical parameter chosen from the section modulus and moments of inertia of an osseous part, and

. a chemical parameter chosen from the water composition, fat composition and bone composition of an anatomical part comprising said osseous body,

. or any combination of at least two of the preceding parameters.

18. Method according to one of the preceding claims, in which the composite index is a combination of at least two parameters, of which

- one is chosen from among the specific parameters of the bone geometry and the physical parameters: the angle, length, surface, volume, bone mineral density and mass of an osseous part, and
- the other is chosen from among the chemical and physical parameters: the water composition, fat composition, bone composition of an anatomical part comprising the osseous body, and the section modulus and moments of inertia of an osseous part.

19. Device for radiographic imaging, comprising:

- calculation means (17) designed to calculate first digitized radiological data from signals delivered by means (6) of detection of X-rays and corresponding to pixels of a first image of an anatomical part comprising an osseous body and scanned, in a first incidence, with a beam of X-rays having an energy spectrum distributed about at least two energies, these first data comprising, for each pixel, coordinates of the pixel in the first image and absorptiometry values designed to calculate the bone mineral density of the osseous body, referred to a surface area unit, and

- storage means for storing at least one three-dimensional generic model of said osseous body,

characterized in that the calculation means (17) are also designed to determine the value of a composite index using, on the one hand, first digitized radiological data, and, on the other hand, at least one three-dimensional generic model of said osseous body, stored in the storage means.

20. Device according to Claim 19, comprising in addition:
    - radiation-generating means (5) designed to generate, in at least a first incidence, at least one beam of X-rays (10, 11) having an energy spectrum distributed about at least two energies and to scan at least one anatomical part comprising said osseous body,
    - means of detection (6) designed to detect the energy of the radiation corresponding to the X-rays scanning, in the first incidence, each anatomical part comprising said osseous body and transmitted by each of the scanned parts, and to deliver, from the detection means (6), signals corresponding to the radiation transmitted,
    - means for digitizing and recording the signals delivered by the detection means (6) and corresponding at least to the first incidence, in order to constitute the first radiological data.

21. Device according to Claim 20, in which:
    - the radiation-generating means (5) are also designed to generate, in a second incidence not parallel to the first incidence, a beam of X-rays having an energy spectrum distributed about at least one energy, and to scan at least one anatomical part comprising said osseous body,

- the means of detection (6) are also designed to detect the energy of the radiation corresponding to the X-rays scanning, in the second incidence, each anatomical part comprising said osseous body and transmitted by each of the scanned parts, and to deliver signals corresponding to the radiation transmitted,
- the means of digitization and recording are also designed to digitize and record the signals delivered by the detection means and corresponding to the second incidence, in order to constitute second radiological data.

22. Device according to one of Claims 20 and 21, in which:
    - the radiation-generating means (5) consist of a single X-ray radiation source generating alternately two X-ray beams, each corresponding to a different energy spectrum, this radiation source being movable, relative to said osseous body, in a plane comprising the first incidence and second incidence and also along an axis of translation perpendicular to this plane, and in which
    - the detection means (6) consist of a detector comprising a line of detection cells perpendicular to the axis of translation, the radiation source and the detector being aligned on a source-detector axis parallel to the plane comprising the first incidence and second incidence.

23. Device according to one of Claims 19 to 22, in which the calculation means (17) are designed to plot contours or points of the surface of said osseous body on an image of form:

$$\mathrm{I}m(x,y)=\sum_{i\geq 1} ai.fi.(Si(x,y)).$$

where

- the a_i are real coefficients,
- the f_i are functions of $\mathfrak{R}$ in $\mathfrak{R}$,
- the $S_i(x,y)$ are the absorptiometry values for each pixel (x,y) of said image obtained with a radiation whose energy distribution corresponds to a spectrum i.

24. Computer program for digital processing of radiographic images, this program executing an operation which consists in calculating first radiological data, from signals delivered by X-ray detection means (6) and corresponding to pixels of a first image of an anatomical part comprising an osseous body and scanned, in a first incidence, with a beam of X-rays having an energy spectrum distributed about at least two energies, these first data comprising, for each pixel, coordinates of the pixel in the first image and absorptiometry values designed to calculate the bone mineral density of the osseous body, referred to a surface area unit, and being
characterized in that it executes an operation which consists in determining the value of a composite index using, on the one hand, first digitized radiological data, and, on the other hand, a three-dimensional generic model of said osseous body stored in storage means of a computer.

25. Computer program product comprising program code means stored on a support readable by a computer, in order to execute the method according to one of Claims 1 to 18, when said program product is operating on a computer.